

Comet 19P/Borrelly Orbit Determination for the DS1 Flyby

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ABSTRACT

The Deep Space 1 (DS1) spacecraft flew within approximately 2100 km of comet 19P/Borrelly on 2001 Sep. 22.94 UT. Spacecraft optical navigation (OpNav) images were taken beginning Aug. 25, but the comet was not unambiguously detected until Aug. 29, at a range of 0.233 AU. Already at this point it was evident that the DS1 OpNav observations were inconsistent with predictions, but as more OpNavs were processed at ever-diminishing ranges it became clear that the comet was actually more than 1600 km away from the original ephemeris derived only from ground-based observations.

This is the first time that deep-space OpNav images have been used to update a comet or asteroid ephemeris, and the introduction of such high precision observations was critical to the success of the flyby, although it created new challenges for the comet orbit determination. In particular, the standard modeling of nongravitational accelerations proved inadequate to such an extent that the ground-based data arc was reduced from three apparitions to less than one revolution in order to fit the OpNavs. Furthermore, unusually large (for Borrelly) non-gravitational accelerations, especially in the radial direction, were indicated. This work points out the need for better modeling, perhaps through the introduction of stochastic accelerations.

Even with a much shorter data arc it was clear that precision ground-based astrometry was consistently biased to the northeast, or anti-sun direction, due to a fundamental inconsistency between the ground-based and space-based OpNav observations. Careful study of both OpNav and ground-based images of Borrelly indicated an asymmetric coma associated with a distinct anti-tail of material in the sunward direction. This asymmetry was not well-modeled by the astrometric reductions, which were based on a best-fitting 2D gaussian. Recomputed astrometry, referenced to the center of the brightest pixel, placed the ground-based data in substantially better agreement with the spacecraft observations, and significantly improved the final ephemeris used by DS1, which was accurate to within about 100 km, with most of the error along the spacecraft line-of-sight.

We postulate that the large outward radial accelerations and the presence of an anti-tail during multiple apparitions could be explained if the rotation pole were pointing roughly sunward during perihelion passage.